

Gas Cloud Kills Thousands At Lake Nyos, Africa: Identifying the Culprit and Saving Lives in the Future

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Collaborators

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Funding

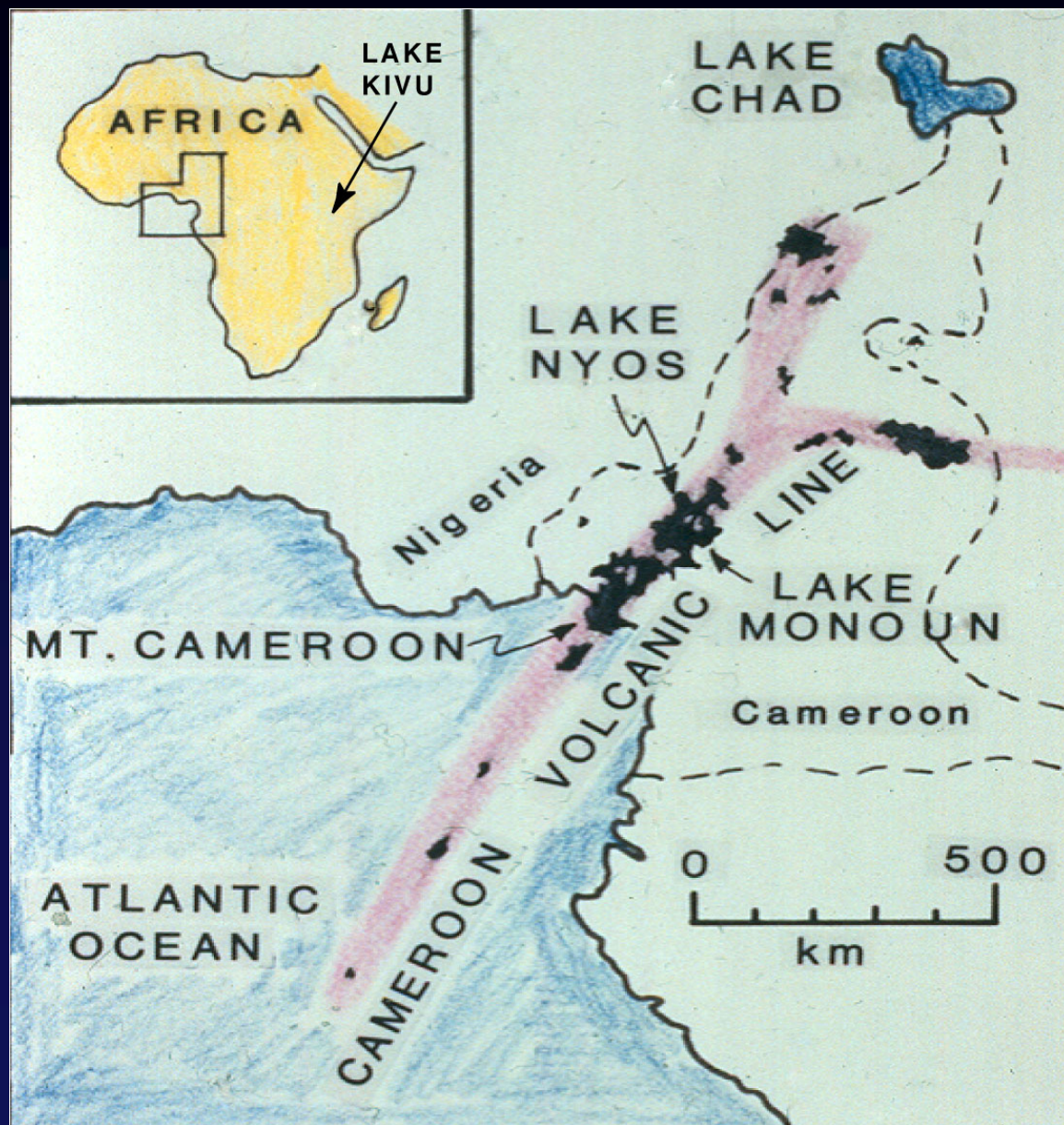
U.S. Agency for International Development
U.S. Geological Survey
National Geographic



The Killer Lakes of Cameroon

1984 Lake Monoun, 37 fatalities

1986 Lake Nyos, 1700 fatalities



Cameroon Volcanic Line

Lake Nyos
Lake Monoun

East African Rift

Lake Kivu



After the calamity: the waters of Nios, which once shimmered a welcoming blue, have now turned a drab shade of reddish-brown

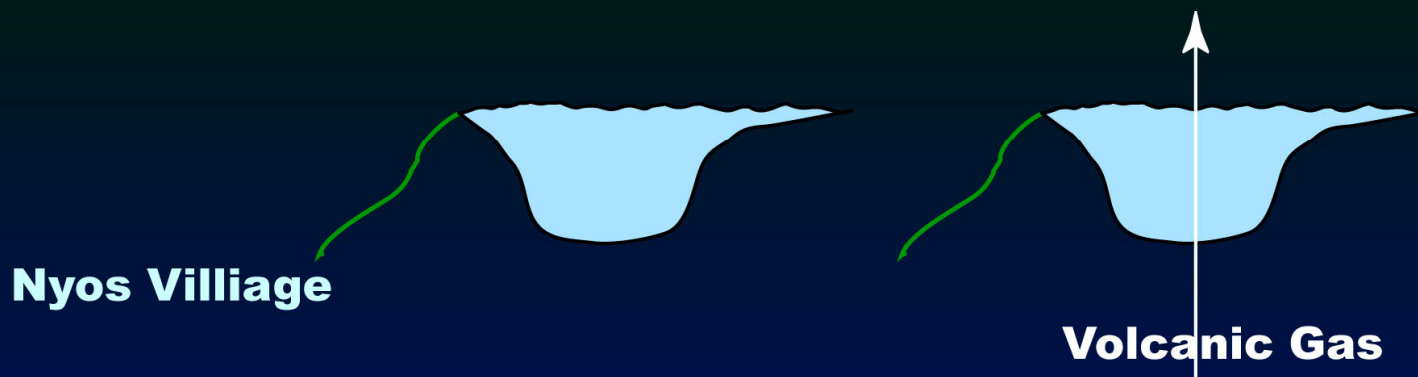
CAMEROON

The Lake of Death

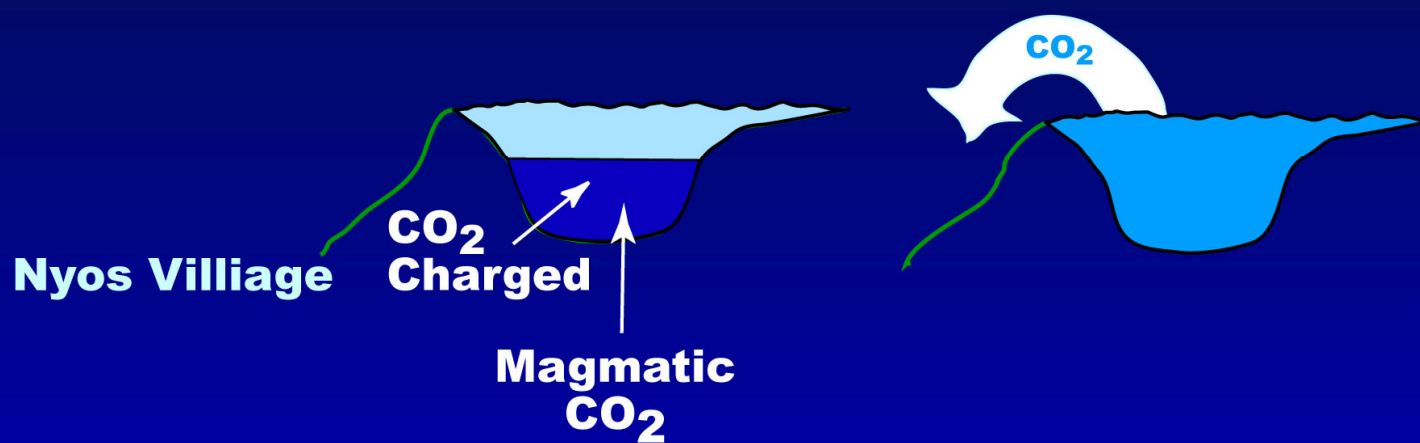


State Department Geoscience Team

Volcanic Gas Explosion Model



Accumulation and Release Model







deaths 19 km
from lake

1 km³ gas



no vegetation damage



no structural disturbance

herd of dead cattle

no agonal struggle



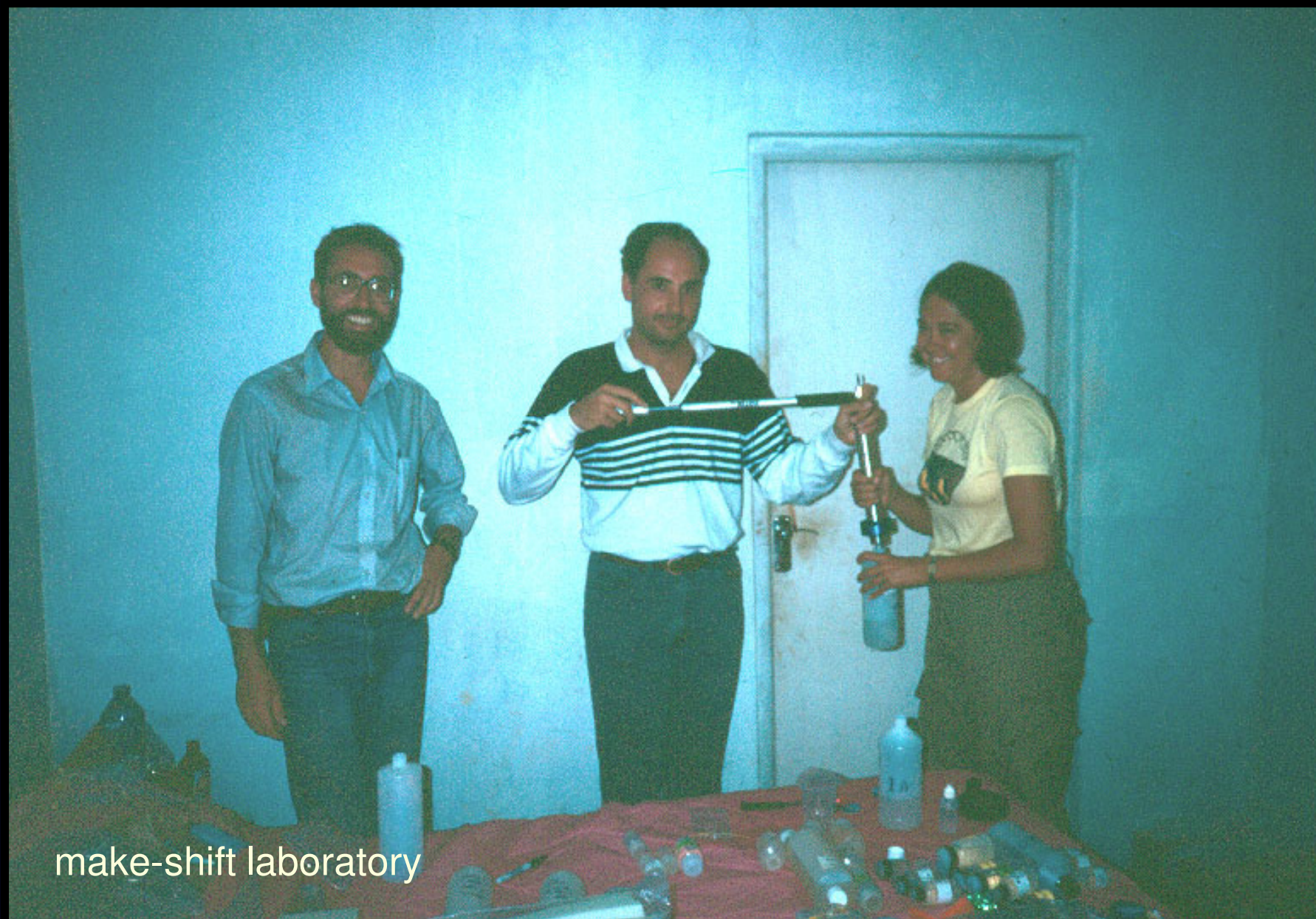
Skin lesions on survivors. Burns??





surface layer of ferric oxyhydroxides





make-shift laboratory

Questions

- 1. What is the gas**
- 2. What is its source**
- 3. How is it transported**
- 4. Where is it stored**
- 5. How is it released**

Characteristics of Gas Dissolved in Lake Nyos

CO₂ comprises >99% of total gas concentration

$$\delta^{13}\text{C}_{\text{CO}_2} = -3.3 \text{ ‰ (PDB)}$$

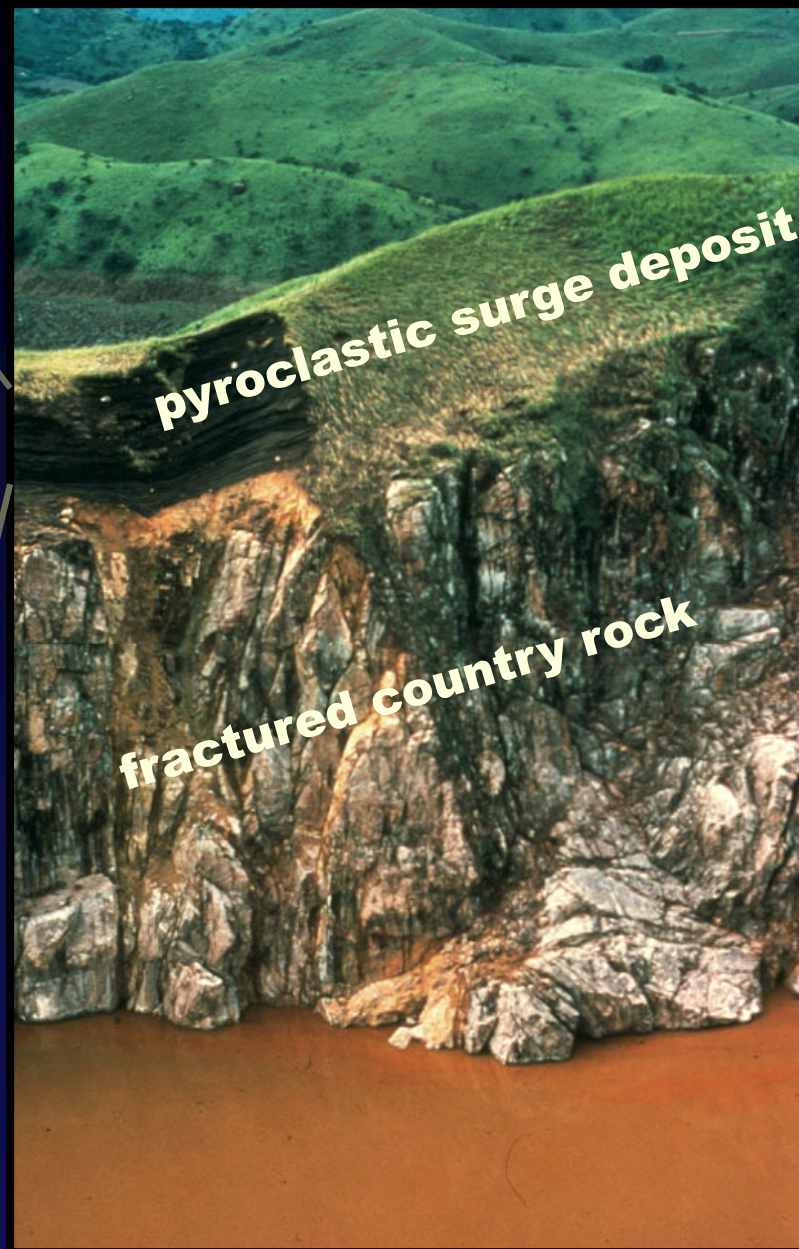
C¹⁴ dating indicates no modern carbon

Trace (<1%) CH₄ , He, Ar, N₂

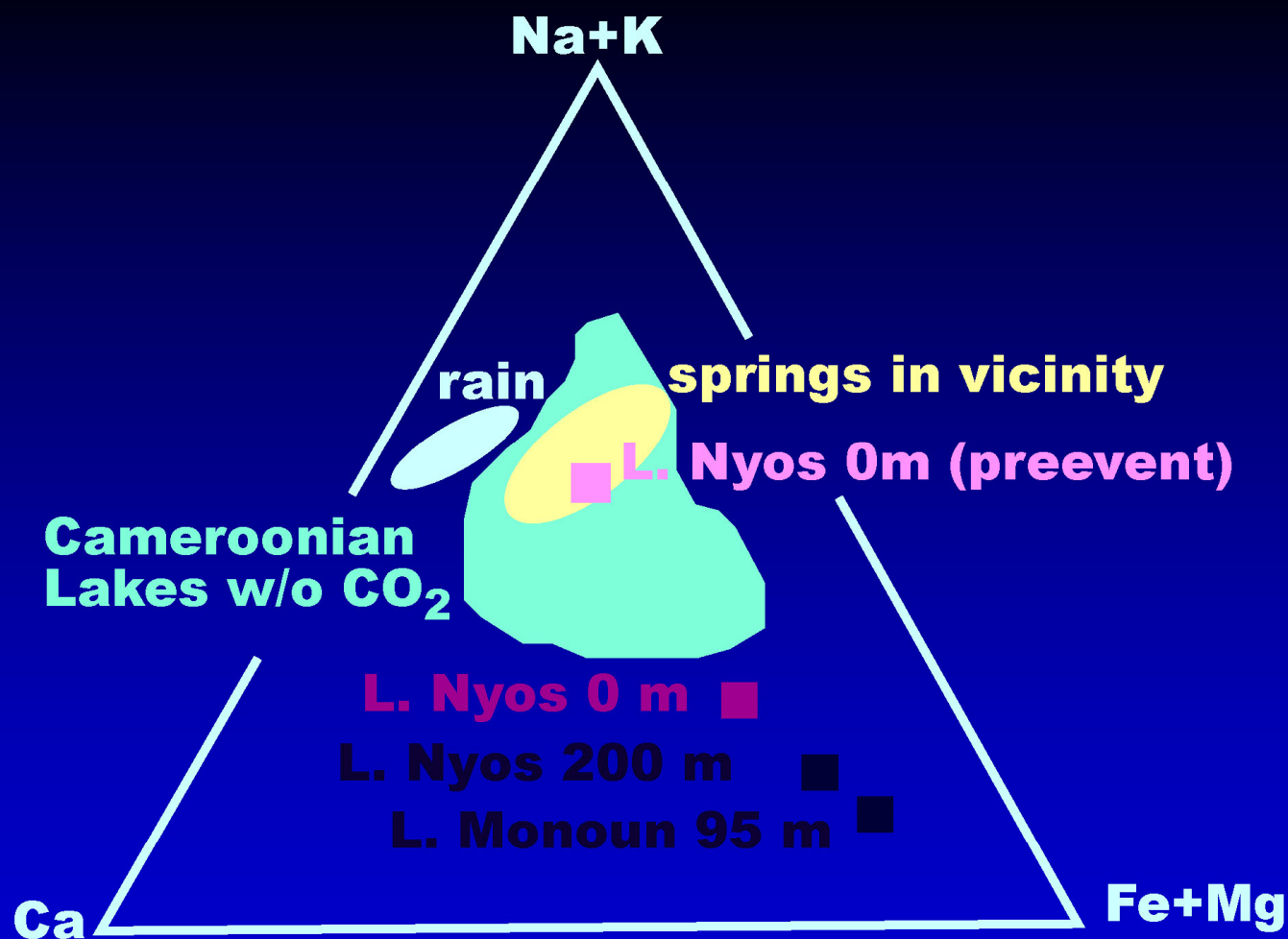
$$\text{He}^{3/4} = 6 \text{ x atmospheric ratio}$$

Magmatic source of CO₂

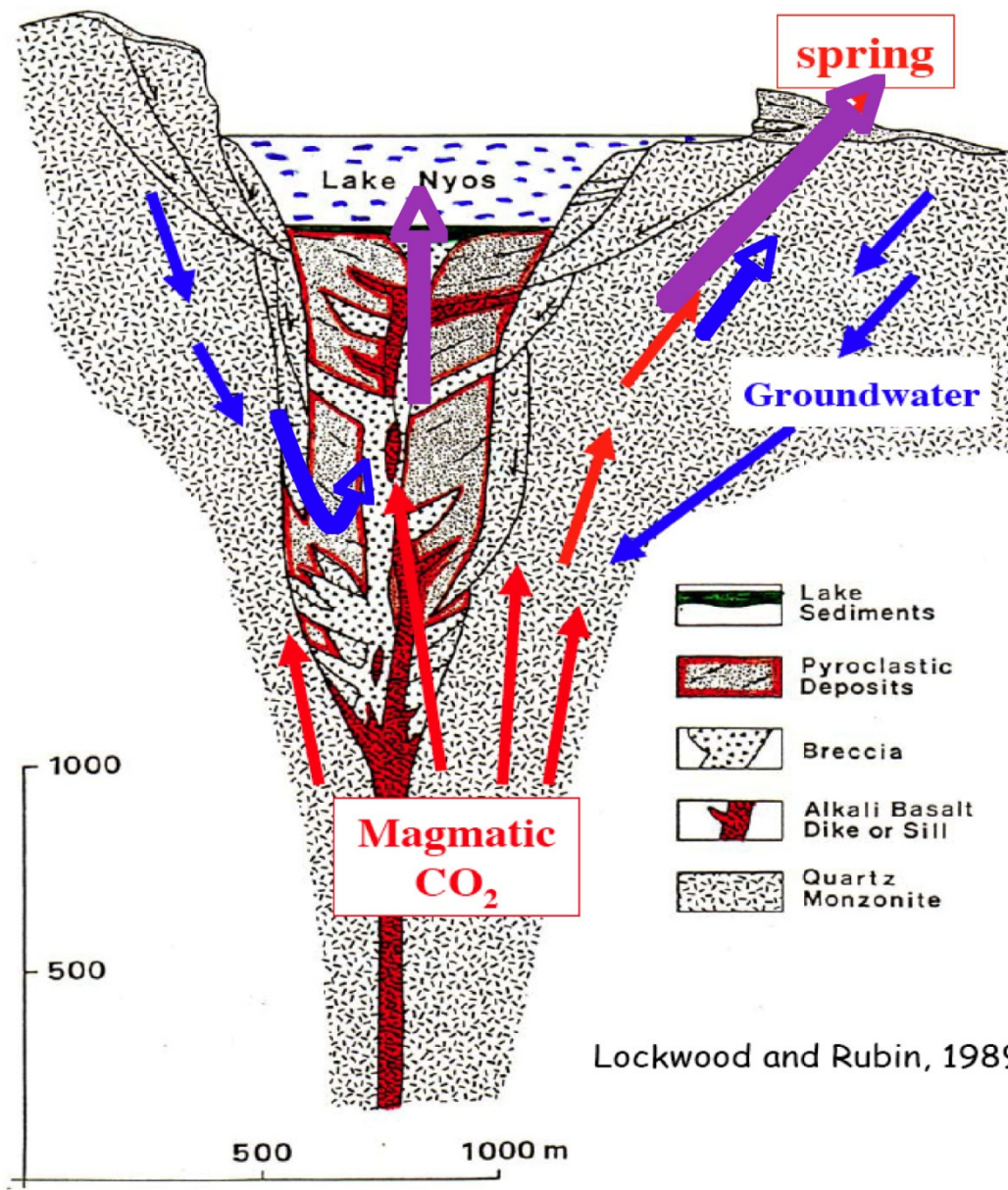
Iherzolite nodule

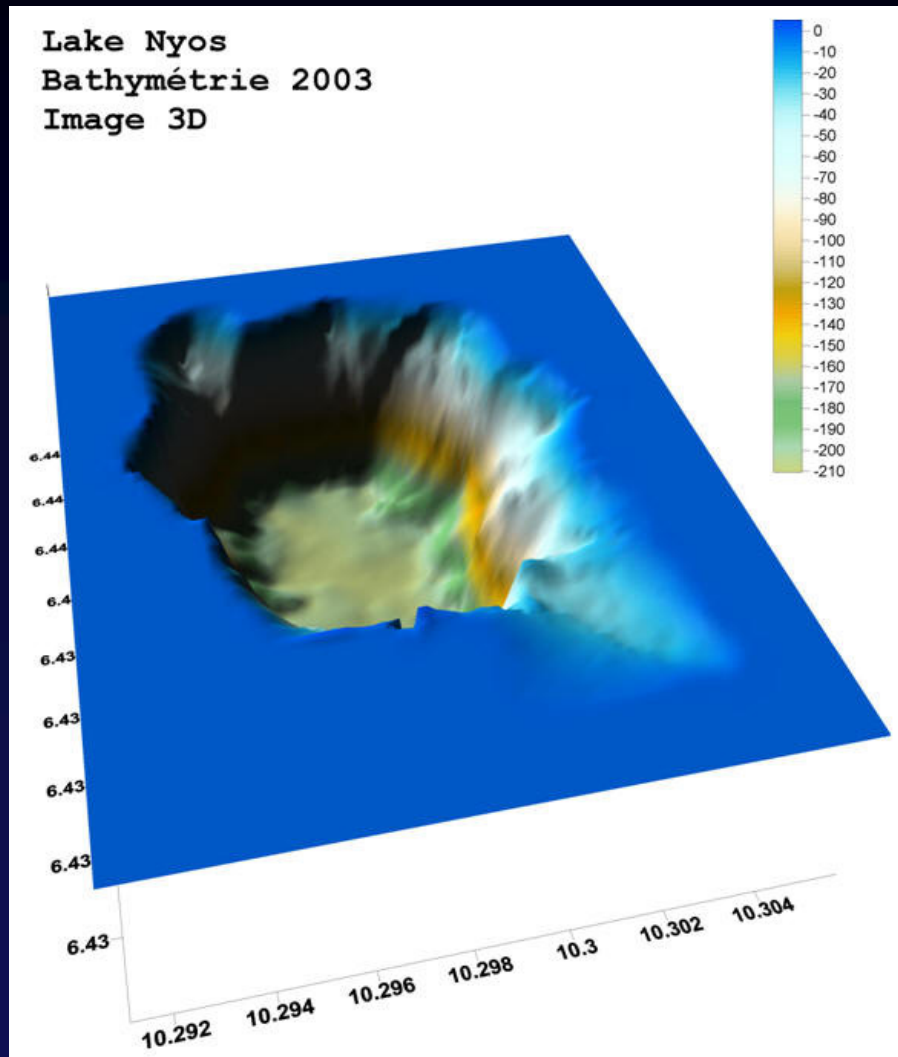


1986 Water Compositions



Hypothetical diatreme structure beneath Lake Nyos

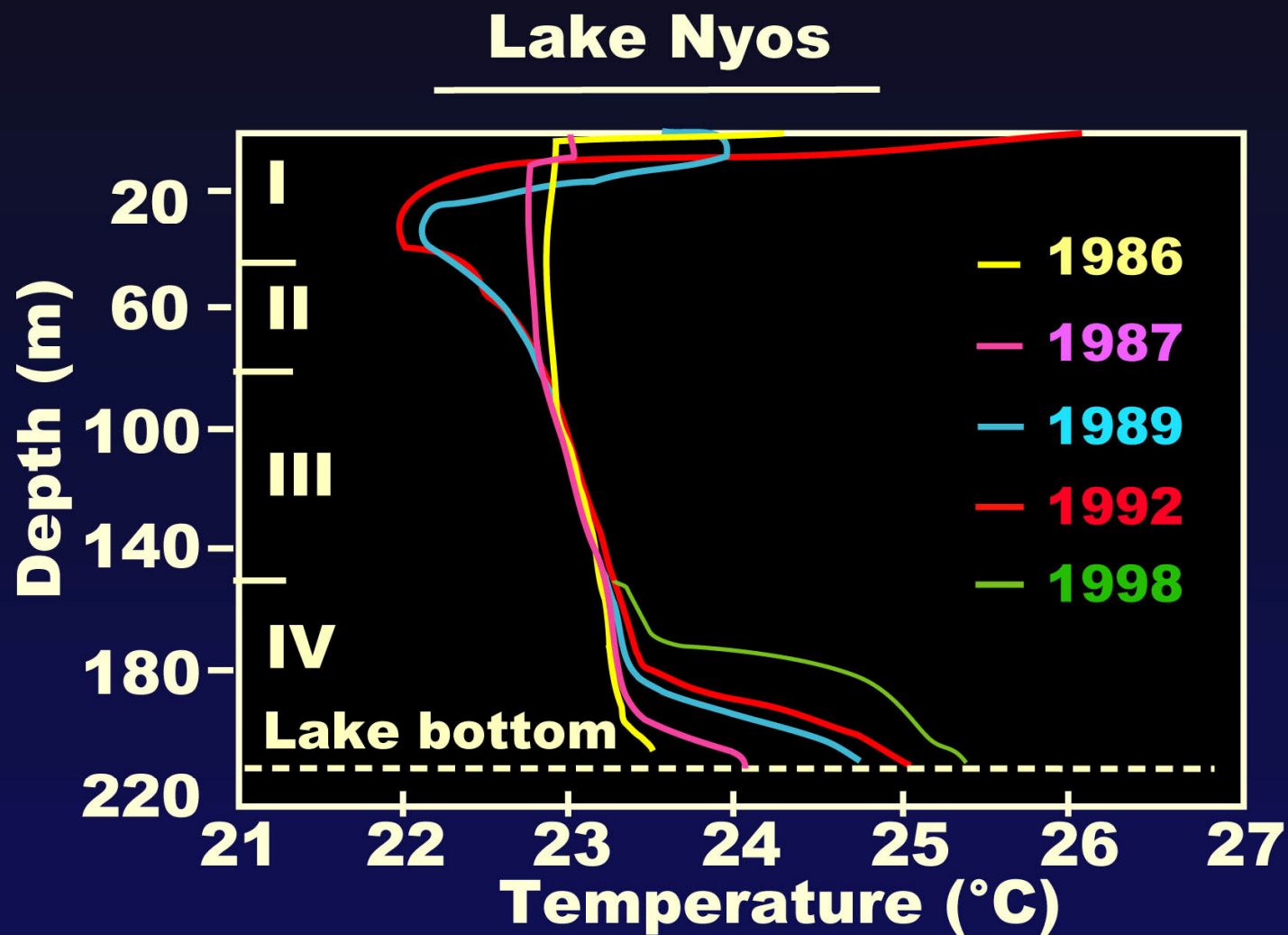




3-D image created by Halbwachs, 2002

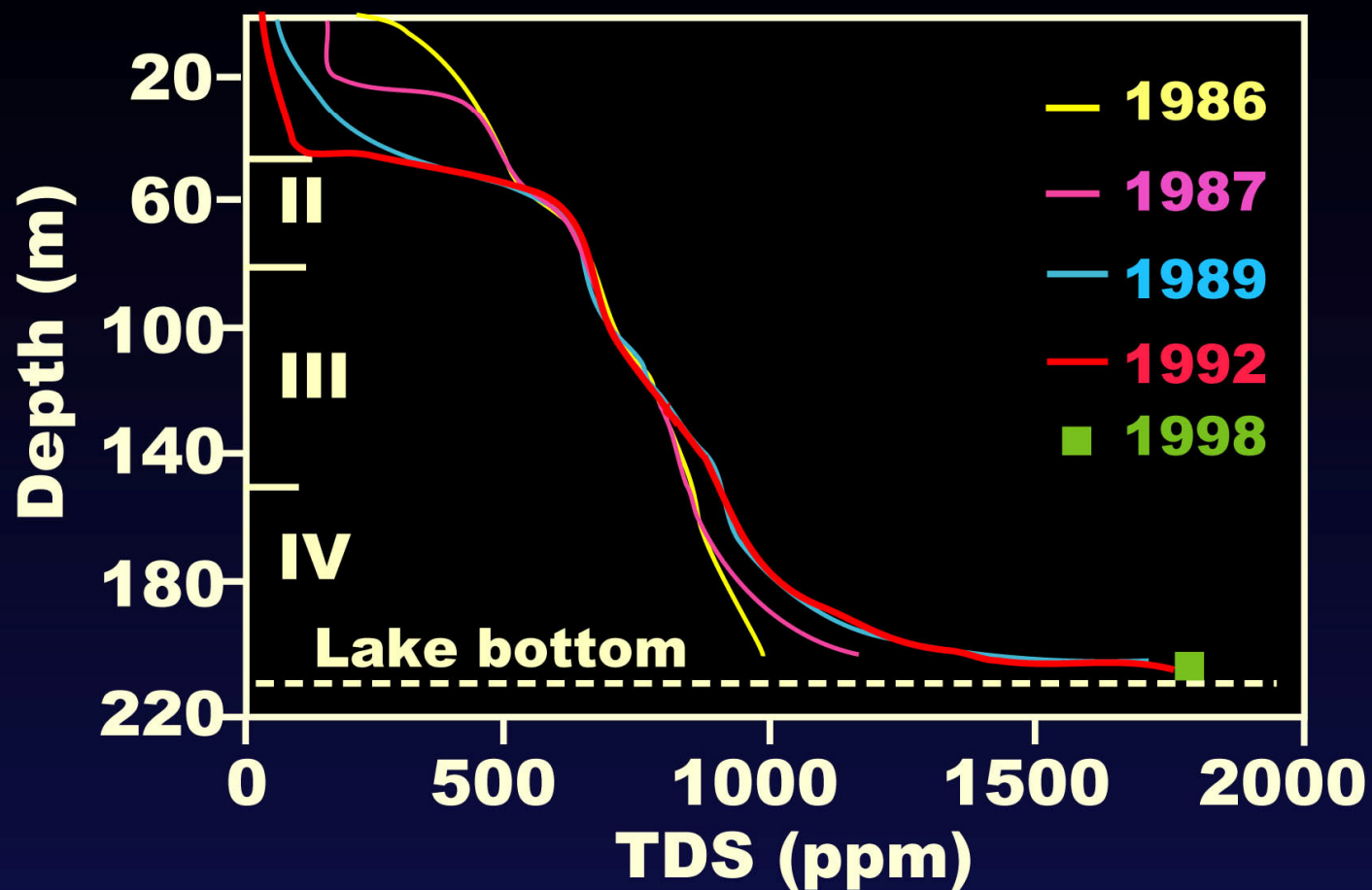


CO_2 -rich spring near lake



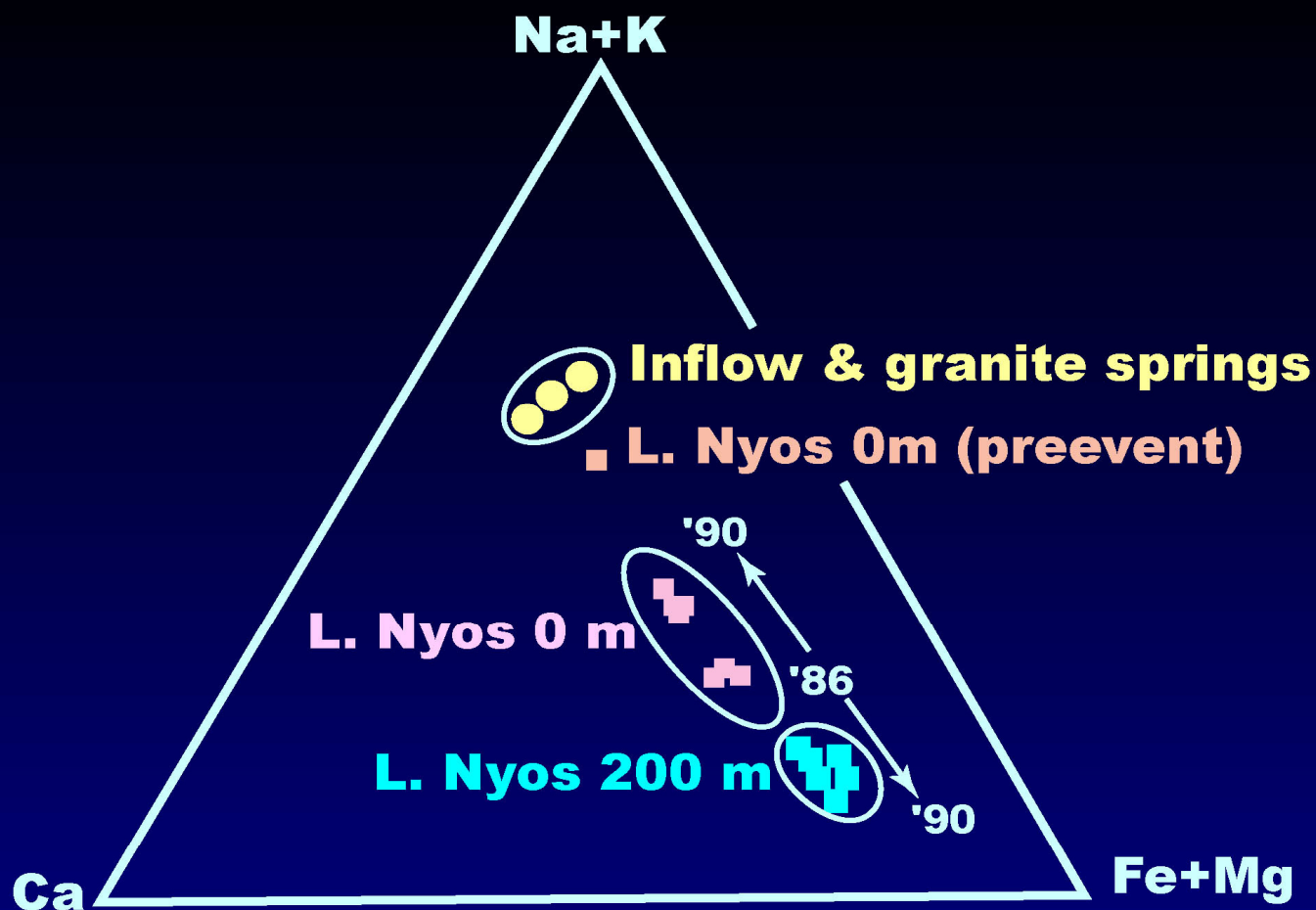
'98 data from Kling et al. 1998

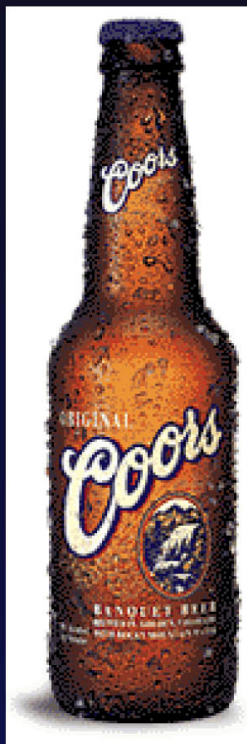
Lake Nyos



'98 datum calculated from Kling et al. 1998

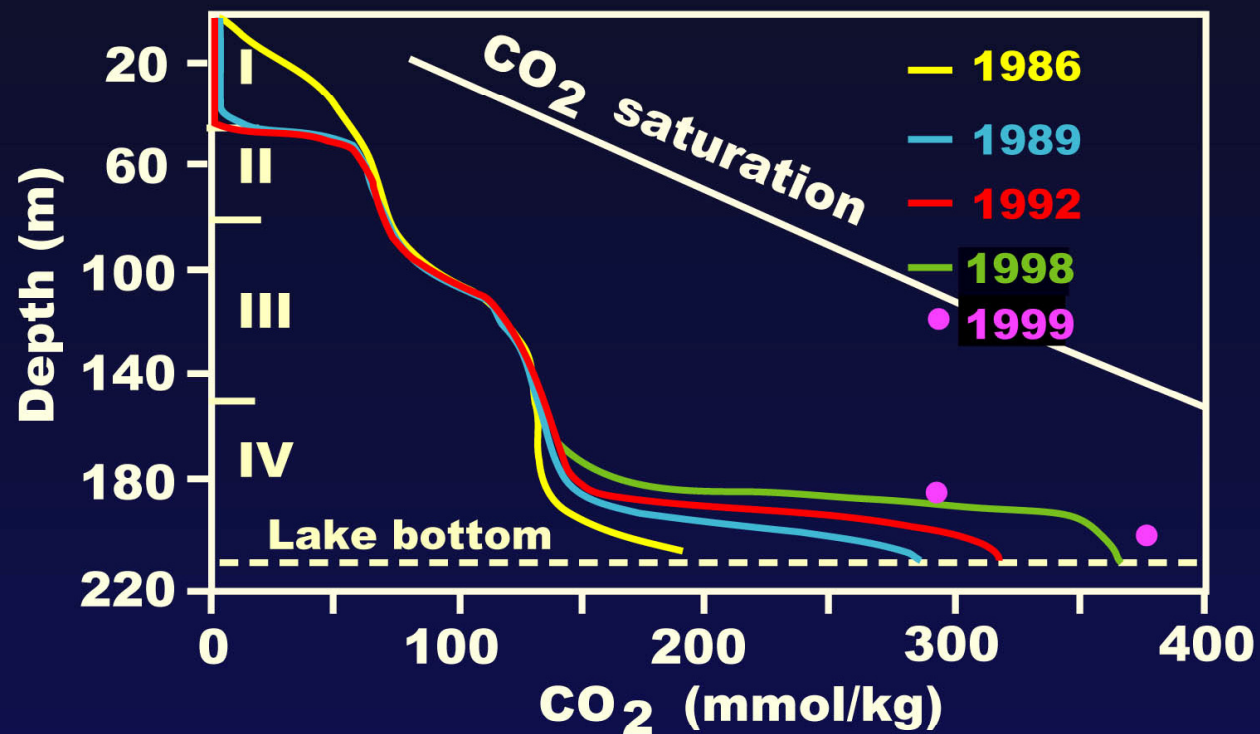
Water Composition 1986 to 1990





≈ 1.1 mmol/kg

Lake Nyos



'98-99 data calculated from Kling et al. (1998;2000)



CO₂ + recharge fluid
← **surface runoff**
precipitation

Temperature profiles

Chemical profiles

Mineral equilibria modeling

Heat Budget

Hydrologic budget

Mass balance calculations

Inferred Characteristics of Recharge Fluid 1992

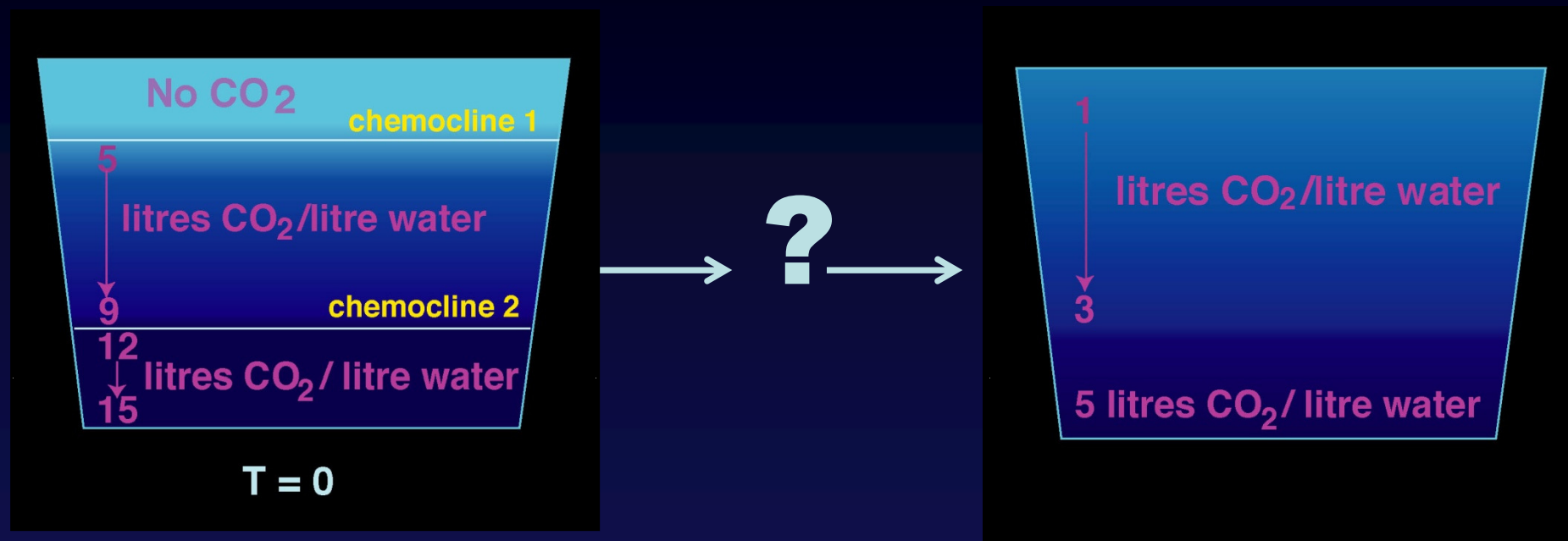
Chemical Composition

TDS	~1800 ppm
Fe + Mg	~68% cation molarity
HCO ₃	only major anion
CO ₂	360 - 650 mmol/kg
CO ₂ flux	= 2.5 x 10 ⁸ mol/yr
Fluid flow	17 - 27 liters/sec
Temperature	26.1 - 28.6 °C

120 yrs to saturate below 50 m

12 yrs to saturate bottommost layer

Catastrophic Degassing of Lake Nyos

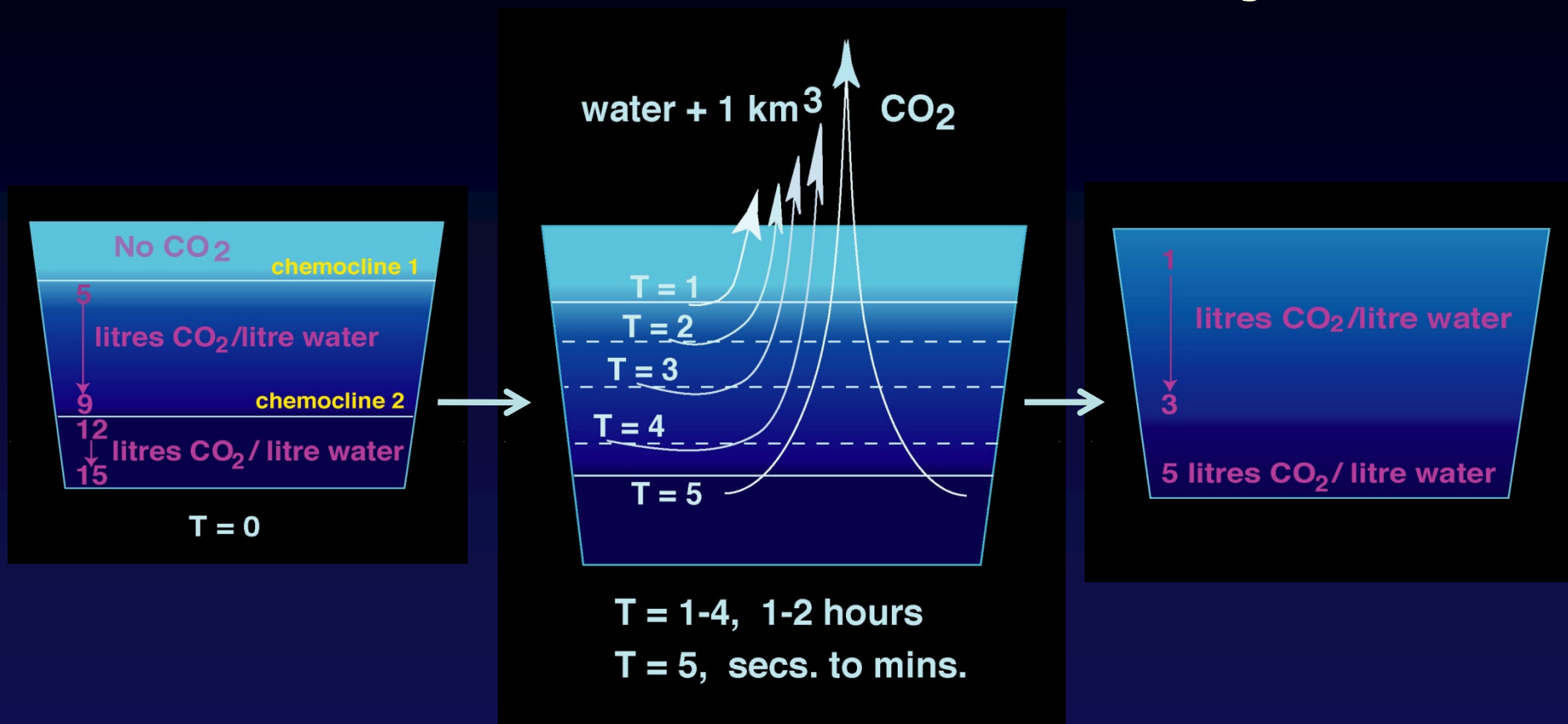


Observations

Before 9:00 PM: Bubbling noise from lake
White cloud over the lake

9:00 PM: Loud explosion from the lake
People die in Nyos Village

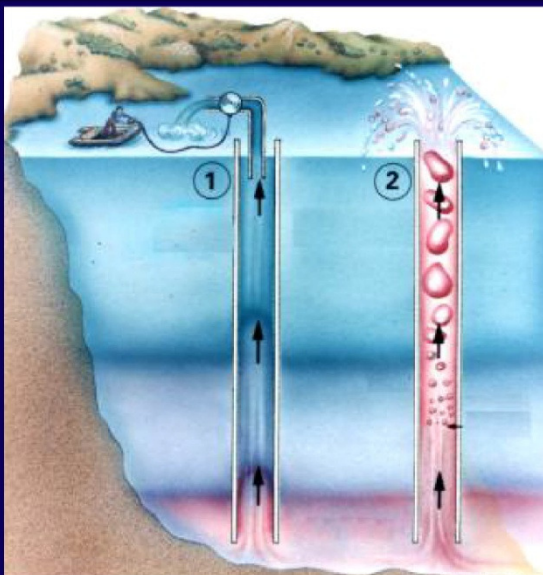
Catastrophic Degassing of Lake Nyos



T1-T4 bubbling noise from lake
white cloud over the lake

T5: loud explosion from the lake
people die in Nyos Village

Degassing Theory



Lake Nyos
270 Mm³ CO₂ ('92)
5 pipes
3-5 years

Lake Monoun
9.5 Mm³ CO₂ ('92)
3 pipes
2 years

figure and data from Halbwachs
<http://perso.wanadoo.fr/mhalb/nyos/project/principle.htm>

French Degassing Experiment 1995



Michael Halbwachs



208 m pipe



deploying platform



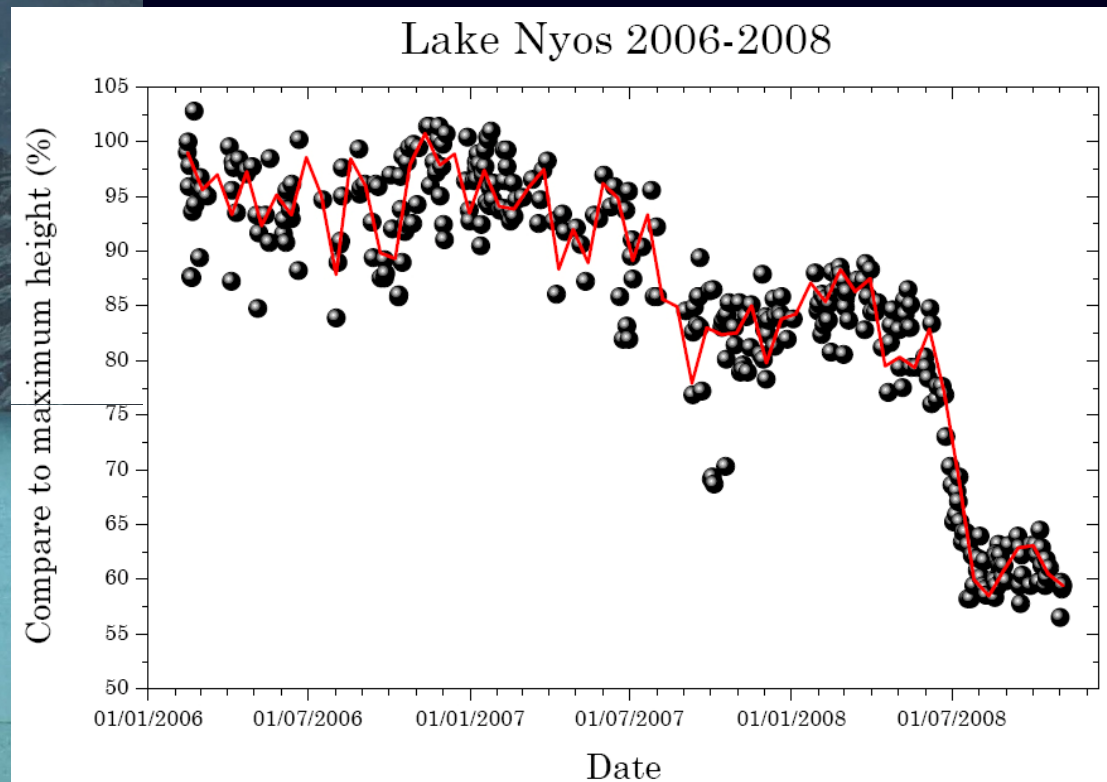
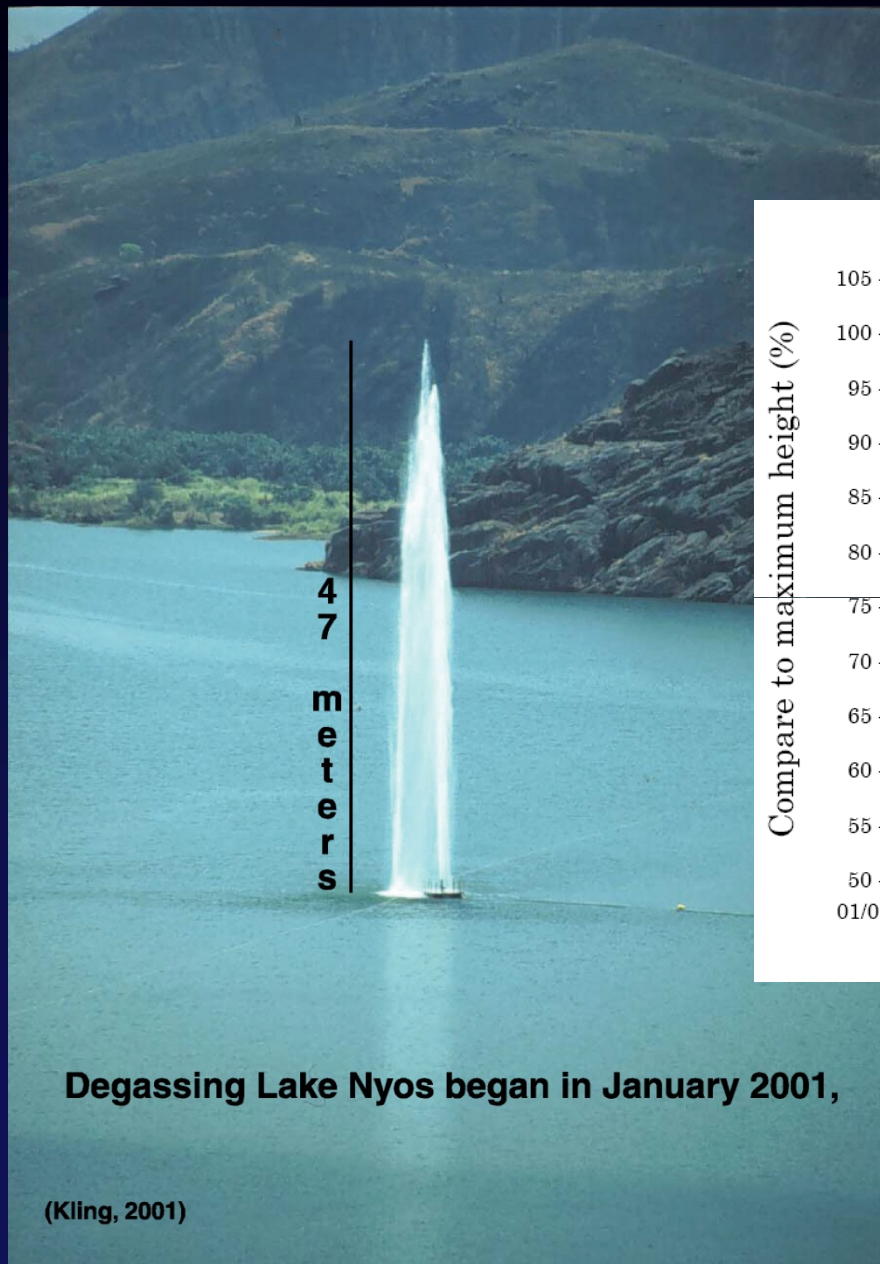
21 m high fountain



risk from degassing CO₂

photos by Bernard Cannet
March, 1995

Degassing Lakes Nyos



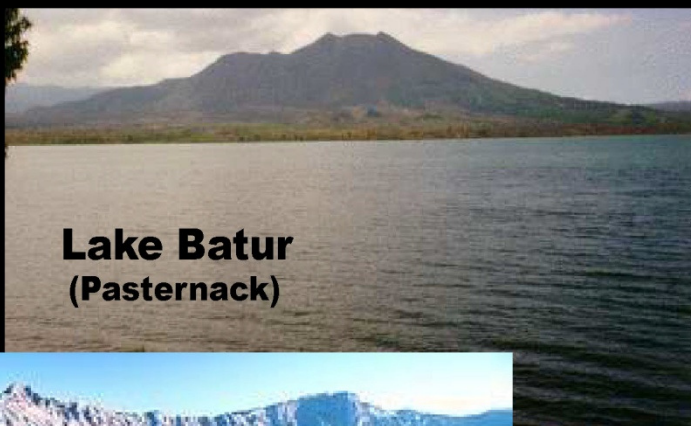
Halbwachs, 2008



August, 1986



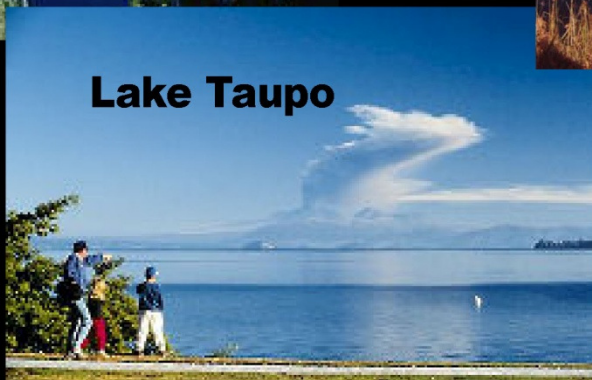
October, 1986



**Lake Batur
(Pasternack)**



Crater Lake



Lake Taupo

Key Variables

Deep stratified Lake

Equatorial climate

Permeable conduit into bottom



**Debre Zgit
(Michálek)**

Steady magmatic CO₂ Source

Time

Lake Kivu and Nyiragongo Volcano



lava dammed lake in East
African rift



CO₂ in East African Rift



**Mazuko in 1977 lava flow
from Nyragongo**

CO₂ vent in bottom



Snuffing of flame by CO₂

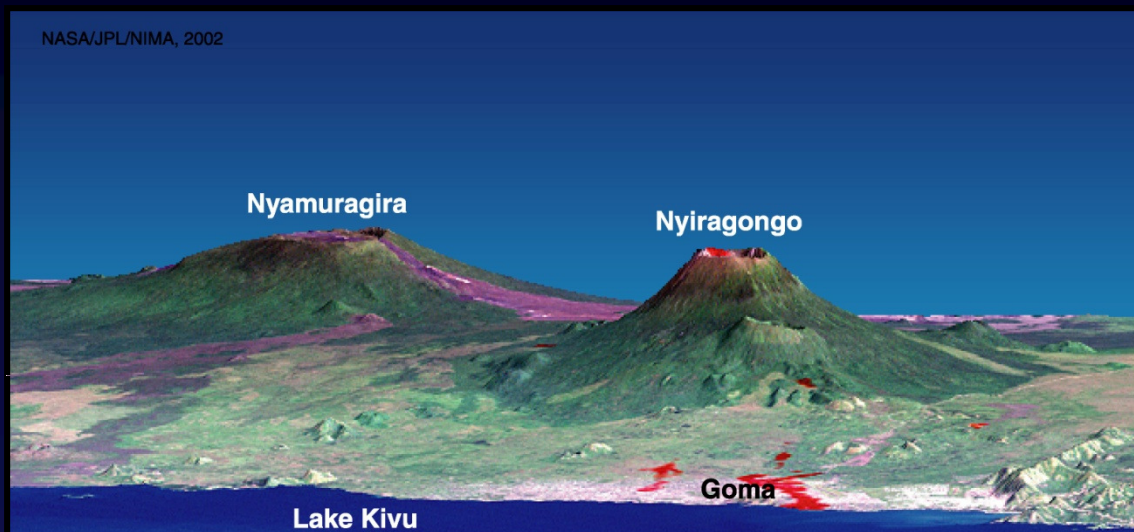


	Lake Nyos	Lake Kivu*
Area (km²)	1.58	2060
Maximum depth (m)	210	500
Lake Volume (km³)	0 .18	580
CO₂ -- bottom water (mol/kg)	360	84
CO₂ volume (km³)	0.5	315
CH₄ -- bottom water (mol/kg)	1.1	16
CH₄ volume (km³)	0.002	63
pH -- bottom water	5.2	7.0
TDS -- bottom water	1800	5700
Water Column Stability (j/m²)	64,000	340,000

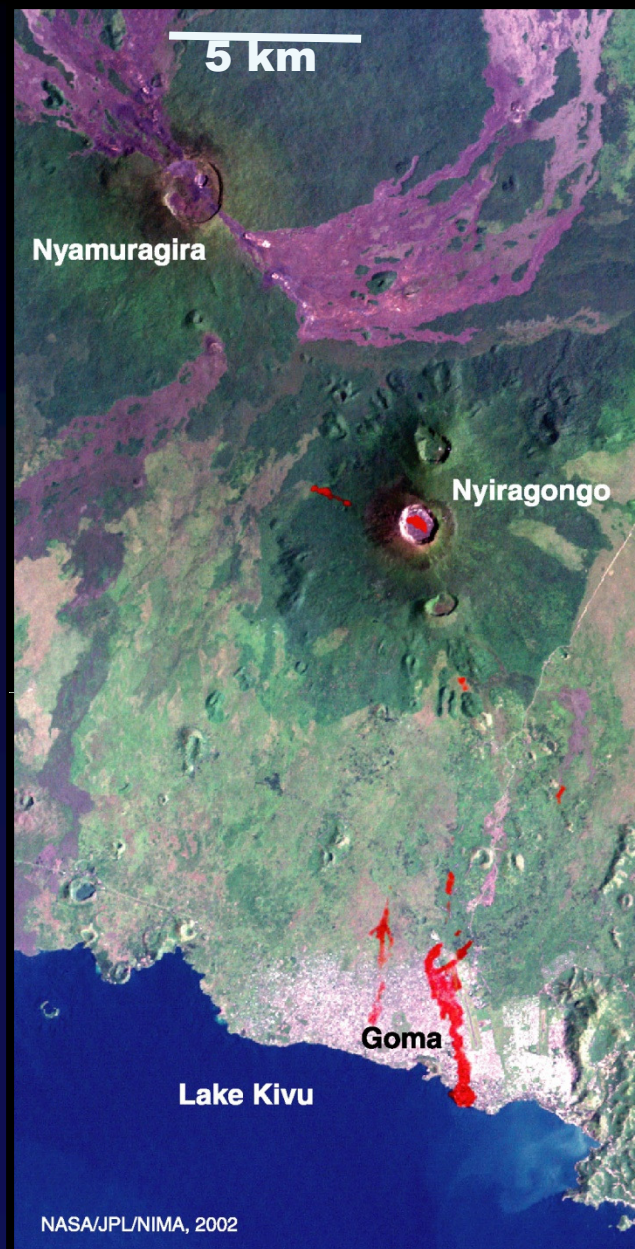
*Kivu data from 1988

'02 Lava flow into Lake Kivu

NASA/JPL/NIMA, 2002



NASA/JPL/NIMA, 2002
Combination of space-born
thermal emission and
reflection radiometer
with Landsat



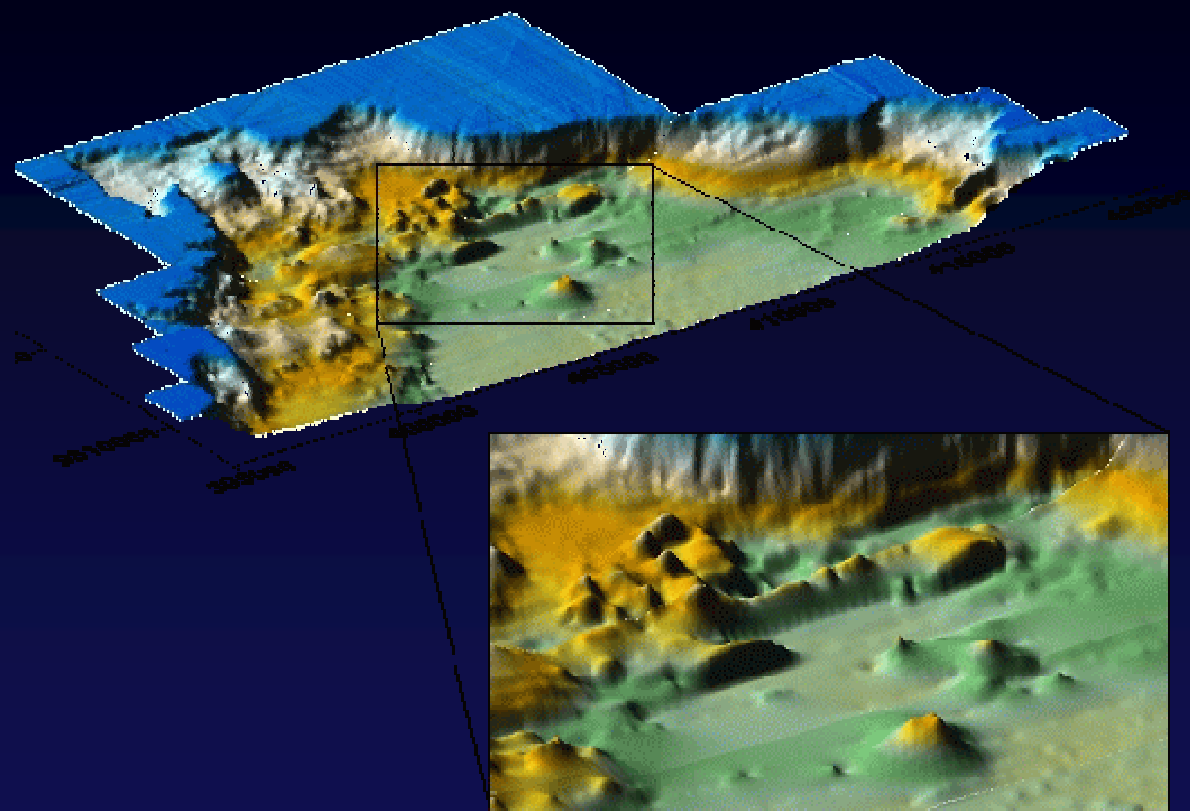


Image generated by Halbwach (2002) from OSEA Co. data



self siphoning

